

Speedy Orthodontics: A Review on Methods of Accelerating Orthodontic Treatment

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ABSTRACT

Long treatment period is one of the major drawbacks in orthodontics which prompts several patients, especially adults, to either stay away from treatment or to look for shorter alternative methods with end results that is not ideal. For that reason, the treatment methods that reduce treatment period without affecting the treatment result is an active area of research in orthodontics today. So demand for shorter treatment duration in society has increased especially in orthodontics. Despite various advancement in different areas of orthodontics, still accelerated tooth movement is research work of academic interest. Because of longer treatment time, there is a chance of increased periodontal insult, decalcification, dental caries and resorption of the root. Long duration treatment is expensive for the patient as well as the orthodontist. The short duration of treatment is requisite to all patients, mainly adults. The best way to reduce treatment time is to speed up or accelerate tooth movements. Various methods have been introduced to increase the rate of tooth movements, such as mechanical stimulation methods, surgical methods, and drugs. That's why this article intends to review and discuss different methods to accelerate orthodontic tooth movement.

KEYWORDS: Corticotomy, Micro-osteoperforations, Piezocision, Paoo, Miro, Low-level laser

INTRODUCTION

Demand for shorter treatment duration in society has increased especially in orthodontics. Despite various advancement in different areas of orthodontics, still accelerated tooth movement is research work of academic interest. Because of longer treatment time, there is a chance of increased periodontal insult, decalcification, dental caries¹⁻³ and resorption of the root.^{4,5} Long duration treatment is expensive for the patient as well as the orthodontist. The short duration of treatment is requisite to all patients, mainly adults. The best way to reduce treatment time is to speed up or accelerate tooth movements. Estimated teeth movement is 0.8 -1.2 mm per month when continuous force is applied.⁶⁻⁹ Sequential remodeling of alveolar bone and periodontal ligament in the presence of mechanical stimulus leads to orthodontic tooth movement. In bone remodeling resorption of bone on pressure site and formation on tension, site occurs.¹⁰ The size of applied force and biological response from periodontal ligament can control orthodontic tooth movement.¹¹ The microenvironment around PDL is changed by application of force on the teeth due to alteration of blood flow. This leads to secretion of inflammatory mediators like cytokines, growth factors, colony stimulating factors, arachidonic acid metabolites, neurotransmitters. Remodeling of bone occurs due to these secretions.^{12,13}

Various methods have been proposed to hasten the rate of

orthodontic tooth movement. The goal of this review article is to register and discuss different methods to accelerate orthodontic tooth movement as well as to discuss advantages and shortcomings of each method.

METHODS TO ACCELERATE ORTHODONTIC TOOTH MOVEMENT

Methods to accelerate orthodontic tooth movement can be studied under different categories:

1. Biological / Pharmacological
2. Physical / Biomechanical stimulation
3. Surgical

1. Biological / Pharmacological approach: A variety of drugs have been used since long to accelerate orthodontic tooth movement and have obtained successful results. Vitamin D, prostaglandin, interleukins, parathyroid hormone etc. are few examples. All of these drugs have several unwanted and unfavourable outcome. To list few example, injection of vitamin D into the PDL results in increase of the levels of enzymes like LDH and CPK. Resorption of the root and a widespread rise in the inflammatory state is caused by Prostaglandin. Hence no drug exists that can safely accelerate orthodontic tooth movement.¹⁴

Effect of Cytokines: Elevated level of cytokines like

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interleukins IL-1, IL-2, IL-3 IL-6, IL-8, and tumor necrosis factor alpha (TNF) were found to play a most important role in bone remodeling. Interleukin-1(IL-1) stimulates osteoclast function through its receptor on osteoclasts. Mechanical stress of orthodontic treatment increases the production of prostaglandin PGE and IL-1 beta in the periodontal ligaments. There is another cytokine RANKL, that is attached to membrane of osteoblasts. This attaches to the RANK on the surface of osteoclast and causes osteoclastogenesis. Competition of osteoprotegerin (OPG) with RANKL prevents osteoclastogenesis. Bone remodeling occurs due to an equilibrium between RANKL- RANK and OPG.^{15,16}

Prostaglandin effect on tooth movement: Prostaglandins (PGs) are inflammatory mediator that acts on nearby cells. It increases the number of osteoclasts and stimulates bone resorption. Experiments were done to show noticeable relationship between PGs, applied force and the acceleration of tooth movement. Fastening tooth movement appears effective at a lower concentration of (0.1 micro gm). Higher concentration leads to resorption of root. Administration of Prostaglandins Systemically is reported to have better effect than administering locally.

Effect of Vitamin D on tooth movement: Vitamin D has a vital function in hastening tooth movement. 1,25 dihydroxycholecalciferol is a hormonal form of vitamin D and plays a significant role in calcium balance. Vitamin D and 1,25,2(OH)D₃, which is an active metabolite of vitamin D along with parathyroid hormone (PTH) and calcitonin, control the amount of calcium and phosphorus levels. Vitamin D receptors have been demonstrated in osteoblasts, osteoclast precursors and in active osteoclasts. Collins and Sinclair (1988) confirmed about faster rate of tooth movement during canine retraction due to increased number of osteoclasts by injecting vitamin D metabolite, 1,25-dihydroxy cholecalciferol intraligamentally.¹⁷

Parathyroid hormone: Its main effect is an increase in the concentration of calcium in the blood; consequently, it stimulates bone resorption. Effect of PTH on osteoclasts occur through the fabrication of RANK-L (Receptor activator of nuclear factor kappa -B ligand), a protein playing a crucial role in osteoclast formation and activity. In 1970s, animal studies demonstrated that PTH could induce an increase in bone turnover that would accelerate orthodontic tooth movement

2. Physical / Biomechanical stimulation: Another move towards accelerating tooth movement is by using device-assisted therapy. This technique includes direct electric currents, pulsed electromagnetic field, static magnetic field, resonance vibration, and low level laser. The idea of using physical or mechanical stimulation was derived from the thought that when orthodontic forces are applied on bone, causes bone to bend (bone bending theory) and leads to development of bioelectric potential. The convex site will be positively charged attracting osteoclasts and concave site will be negatively charged attracting osteoblasts.¹⁸ When discontinuous forces were applied,

resulted in creation of bioelectrical potential and lead to the idea of using cyclic forces and vibrations. It has been observed that applying vibrations for different duration per day accelerated tooth movements between 15% and 30% in animal experiment.^{19,20}

Cyclical force device effect on tooth movement: Use of the cyclical force device in patients has resulted in a tooth movement of 2 to 3 mm /month. The device is vibrated at the rate of 20 to 30 Hz, for 20 min/day.²¹ On the 1st molar of Wistar rats, Ni-Ti expansion spring was placed and a vibratory force at the rate of 60 Hz, 1 m/s² was applied by Nishimura et al (2008). It was found that the rats that received the vibration showed increased orthodontic tooth movement. In the sectioned samples, they observed increased RANKL expression in the fibroblasts and osteoclasts of the periodontal ligament of the rats those received vibration.¹⁹

Effect of direct electric current on tooth movement: Another method is use of direct electric current. This technique was tested only on animals. Direct current was applied to the anode at the pressure sites and cathode at the tension sites thus generating local responses and acceleration of bone remodeling.²² Their studies were more successful than the prior attempts because electrodes were placed as close as possible to the moving tooth. By using enzymes and glucose as fuel, a number of attempts were made to develop biocatalytic fuel cells to produce electricity intra orally.^{23,24} Additional research is required to develop direct electric devices.

Low level laser therapy: Low level laser therapy (LLLT) or photobiomodulation is one of the potential approach in recent time. The biostimulatory effect of low level laser radiation is under research since 1966. Laser has a biostimulatory effect on bone regeneration, which has been shown in the midpalatal suture during rapid palatal expansion,²⁵ stimulate synthesis of collagen in bone which is major matrix protein. There is stimulation of regeneration of bone in cases of bone fracture and at the site of extraction.^{26,27} It has been observed that laser light stimulates the osteoclast, osteoblast, and fibroblast proliferation. In this manner remodeling of bone is affected and results in accelerated tooth movement. In accelerating tooth movement, the mechanism involved is by the production of ATP and activation of cytochrome C.²⁸⁻³⁰ Low energy laser irradiation fastens the rate of tooth movement through RANK / RANKL.

It has been shown by experimental studies on animals that acceleration of tooth movement occurs by application of low level laser. Because of increase in bone remodeling and greater speed of tooth movement without adversely affecting periodontium, low level laser therapy can be very useful. It is observed that 800 nm wavelength of laser with 0.25 mW output power causes remarkable stimulation in metabolism of bone, rapid ossification²⁷ and also an acceleration of tooth movement to 1.5-fold in rat experiments.

An increase of 30-60% tooth movement have been shown

by different studies on low level laser therapy. Differences in intensity, frequency of application and the method in which force is applied on the tooth might be the cause of variations amongst the studies. Further research and clinical trial are required to determine the most favourable wavelength, energy, period of use.

3. Surgical approach: The surgical technique has been acknowledged in many case reports. Surgical technique is clinically effective for adult patients, where duration of orthodontic treatment may be crucial. PDL and remodeling of the alveolar bone are the important parameters in tooth movement. After bone grafting, fracture and osteotomy bone turnover increases. A number of surgical approaches to accelerate tooth movement are interseptal alveolar surgery, osteotomy, corticotomy, and Piezocision technique.

The thought of accelerating surgically came after the introduction of Regional Acceleratory Phenomena (RAP) by Frost (1983). In RAP, there is a local reaction to noxious stimulus, resulting tissue formation faster than the normal regional regeneration procedure. This event results in healing to take place 2–10 times faster than normal physiologic healing by enhancing the various healing stages.

Interseptal alveolar surgery: Interseptal alveolar surgery is separated into distraction of PDL or distraction of the dento alveolar bone. The idea of distraction osteogenesis was taken from the earlier studies of limb lengthening. This perception was later adapted into rapid tooth movement. At the time of extraction of the first premolars, interseptal bone distal to the canine is surgically undermined. Therefore the resistance on the pressure site will be reduced. In this technique the woven bone replaces the compact bone and tooth movement is easier and faster due to reduced resistance of the bone.³¹ During the initial phases of tooth movement, mainly in the first week rapid tooth movements were observed.³² In this method, after the extraction of the first premolar 1 to 1.5 mm thickness of interseptal bone distal to the canine is undermined. A round bur is used to deepen the socket till the apical length of canine. Canine is retracted by the activation of an intraoral device directly after the surgery. It was observed that to achieve 6 to 7 mm of retraction of the canine to the socket of the extracted first premolars, around 3 weeks of time was required.³¹ Accelerated canine distraction of the dentoalveolar bone is done by the same principle of the distraction of PDL. Conflicting results concerning the electrical vitality test of the retracted canines were observed. Liou reported 9 positive vitality out of 26 teeth,³¹ while 7 positive vitality out of 20 were observed by Sukurica after the sixth month of retraction.³³ So this technique still have some doubts.

Corticotomy and Osteotomy: Surgical techniques like osteotomy and corticotomy are in use since several years. In osteotomy a segment of the bone is cut into the medullary bone and is separated and then it is moved as a unit.^{34,35} Method like corticotomy is used frequently that involves cutting and perforation of the cortical bone.

Whereas the medullary bone is not perforated. This signifies the decrease in the resistance of cortical bone and accelerates tooth movements.

Corticotomy: Conventional corticotomy procedure involves the elevation of full thickness mucoperiosteal flaps, buccally and/or lingually, followed by giving the corticotomy cuts using either micromotor under irrigation, or piezosurgical instruments. This can be followed by placement of a graft material, wherever required, to augment thickness of bone. In 2001, Wilcko et al reported that a surface computed tomographic evaluation of corticotomized patients clearly showed a transient localized demineralization remineralization process consistent with the accelerated wound healing pattern of the regional acceleratory phenomenon.³⁶

Advantages

- Corticotomy procedure causes minimal changes in the periodontal attachment apparatus.
- It has been proven successfully by many authors to accelerate tooth movement.
- Augmentation of bone will avoid periodontal defects.

Disadvantages

- Invasive procedure leading to high morbidity.
- Chances of damage to adjacent vital structures.
- Post operative pain and swelling.
- Chances of infection or avascular necrosis.
- Low acceptance by the patient.

A substitute of surgically injuring the bone with minimal invasive procedure and without flap elevation was given by Park et al (2006) and Kim et al (2009) known as corticision technique. Reinforced scalpel and mallet were used to cut through the gingiva and cortical bone. This technique had drawbacks such as inability to place grafts.³⁷

Piezocision technique: Dibart et al.(2009), introduced a flapless method of corticotomy using piezosurgery to decrease the morbidity related with conventional corticotomy.³⁸ Surgery was done one week after placement of orthodontic appliance, under local anaesthesia in this technique. Vertical incisions in gingiva, were made buccally below the interdental papilla in the attached gingiva. These incisions go through the periosteum and contact the buccal cortical bone. Piezo surgical knife (Ultrasonic instrument Piezotome) used to make the corticotomy cuts through the earlier made incisions to a depth of 3 mm.³⁹ Tunnelling is done using an elevator inserted between the incisions, to create enough space to accept a graft material only in those areas requiring bone augmentation. No suturing is needed, except for those areas, where the graft material needs to be stabilized. Advantages are minimum invasiveness and better patient acceptance. Disadvantages are risk of damaging root, as incisions and corticotomies are “blindly” done.

Micro-Osteoperforations (Alveocentesis): Propel Orthodontics introduced a device called Propel, to further

decrease the invasive nature of surgical irritation of bone. This process was called Alveocentesis, which exactly translates to puncturing bone.⁴⁰ This device is available as sterile disposable ready to use device. The device has a variable depth dial and indicating arrow on the body of driver. Depth dial can be placed to 0 mm, 3 mm, 5 mm, and 7 mm of tip depth according to the area of action. Expression of inflammatory markers can be encouraged by carrying out micro-osteoperforations (MOPs) and subsequently leading to rise in osteoclast activity and the rate of orthodontic tooth movement. This has been revealed by prior animal studies.

Role of Periodontal Therapy in Rapid Tooth Movement: A new technique that combined selective decortication facilitated orthodontic technique and alveolar augmentation was introduced by Wilcko and Ferguson et al.^{41,42} This method is acknowledged as periodontally accelerated osteogenic orthodontics (PAOO). This procedure permits teeth to be moved 2-3 times in 1/3rd to 1/4th the time required for traditional orthodontic treatment.⁴¹ periodontally accelerated osteogenic orthodontics (PAOO) has been implicated as an adult orthodontic therapeutic modality.

Frost and Jee in 1983 postulated Regional acceleratory phenomenon.^{43,44} The decortication of bone effects in an increased yield of alveolar spongiosa with areas of alveolar demineralization. This marks an osteopenia, where its mineral content temporarily decreased. This enables teeth to be moved more speedily through the collagenous soft tissue matrix of the bone.^{42,44,45} Following the completion of orthodontic treatment, remineralization takes place resulting in greater stability in the orthodontic treatment outcome.

Selective decortications done labially and lingually using round burs and water irrigation. Piezoelectric knife can also be used to achieve corticotomies.³⁸ Between the roots of teeth, corticotomy cuts are given vertically that is short of the alveolar crest. The vertical cut extends from a point 2-3 mm below the crest of the alveolar bone to a point 2mm apical to the apices of the roots.⁴⁶ Scalloped horizontal corticotomy cuts are given to unite vertical cuts. To enhance the blood supply to the graft material, cortical perforations are prepared at selected areas.³⁶ In decorticated areas bone graft materials are placed. The frequently used materials include autogenous bone, decalcified freeze dried bone allograft, deproteinized bovine bone or a combination of these.^{46,47}

Periodontal accelerated osteogenic orthodontics has shown due to the addition of bone grafts results in increased alveolar bone thickness, considerable reduction in treatment duration, better post orthodontic stability and less incidence of root resorption compared to the conventional orthodontic treatment. However, long term treatment outcome of PAOO is still unavailable as the technique is still relatively new.

Minimally invasive rapid orthodontics (MIRO): Jofre et al. (2013) developed the minimally invasive rapid orthodontic method of accelerating tooth movement.

Metal markers were used as radiographic guides or references for precise placement of the incisions and the corticotomy cuts. In between each tooth, the metal guides are placed perpendicular to the main arch wire. Digital radiographs are taken to make sure that the metal guides are not superimposed over the tooth roots. After confirmation, incisions and piezoelectric corticotomy can be performed using the metal guides as references. This improves the accuracy of the procedure.⁴⁸

Further improvement of this technique was done by Cassetta and Giansanti (2016). They developed a custom made, computer-aided designed and computer-aided manufactured, 3-D printed surgical templates. The slots designed in this surgical templates guides scalpel blade and then a piezoelectric cutting blade. This technique helps in obtaining a minimally-invasive, flapless piezoelectric corticotomy with minimal discomfort and surgical complications to the patient.⁴⁹

Laser assisted flapless corticotomy: Erbium lasers when used on hard tissues, the water present inside the hard tissues gets heated up. Because the water is transformed to steam, a mini-explosion occurs and the hard tissue is "ablated" or removed.⁵⁰ Research was done on Erbium lasers' function in corticotomy facilitated orthodontics. It has a considerable advantages over the conventional corticotomy technique, for example less invasive than bone cutting burs, absence of mechanical vibration, free and elaborate cuts and aseptic effects. This makes it a more patient friendly substitute.⁵¹

Study carried out by Seifi et al. (2012),⁵² Salman and Ali (2014),⁵³ Savard (2016)⁵⁴ observed that the amount of orthodontic tooth movement in the experimental group was significantly greater than that of the control group. However, the technical limitations and the lack of depth control of the lasers, needs to be overcome.

CONCLUSION

Since many days, orthodontic patients have been demanding for shorter treatment duration. At present we have various methods that can accelerate orthodontic tooth movement. The recent methods such as piezocision, microosteoperforations, lasers and mechanical vibration have reduced or eliminated the invasive nature of prior procedures used to accomplish the Regional Acceleratory Phenomenon. Further clinical research is required to investigate and safely approve a particular method of accelerating orthodontic tooth movement.

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